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SPRING BARLEY YIELD AND PRODUCTIVITY COMPONENTS AS AFFECTED BY NITROGEN FERTILIZATION AND WEATHER CONDITIONS

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Abstract

Effects of nitrogen fertilizers and weather conditions on spring barley yield, its productivity components and protein content were studied at the Rumokai Experimental Station of the Lithuanian Institute of Agriculture during the periods 1998-2000 and 2003-2004. The soil of the experimental site is *Hapli-Epihypogleyic Luvisol*. Nitrogen rates 0 and 90 kg ha^{-1} were tested.

The experimental findings showed positive and significant correlation between the spring barley yield and the amount of rainfall in May (correlation coefficient 0.81**) and negative and significant correlation with the amount of rainfall in June and July (correlation coefficients -0.93** and -0.41*, respectively). Significant, though weak correlation was identified between nitrogen fertilizer application and grain yield. Statistical calculations between the grain yield and its structural components showed that the yield was mostly dependent on the number of productive stems and on the number of grain per ear. The number of productive stems was more affected by nitrogen fertilizers than by the weather conditions, and the number of grain per ear was more dependent on the rainfall in May and June. Barley population density did not have any direct effect on the yield, however, it affected the number of productive stems and gain number per ear. Protein yield strongly correlated with grain yield and was little dependent on protein concentration in grain

Key words: spring barley, nitrogen fertilizer, amount of precipitation, yield, protein content in grain.

Introduction

Growing of spring barley is an old tradition in Lithuania. Nevertheless, the barley yield and quality are dependent on a wide range of factors. Climatic conditions, growing technologies, diseases and genetic characteristics of varieties are among the main factors, which influence the grain yield and quality parameters /Antanaitis, Švedas, 2000; Petrauskas, Leistrumaitė, 2001; Tamm, Tamm, 2002/.

Proper fertilization of spring barley results in an increased yield, resistance of plants to diseases and pests, and improved quality of grain. From the very start of growing, barley should receive readily available nutrients. At tillering and stem development stages intensive formation of vegetative and generative parts of barley takes place and the only source of nutrients during this period is the soil. If shortage of nutrients occurs during the growing season of plants, some seedlings are lost and no development of additional stems takes place, further resulting in lesser number of grain per ear and smaller grain size. Availability of sufficient content of nitrogen 15-20 days after germination is of utmost importance. In the case of its shortage at the indicated time, ear formation is negatively affected /Bogomazov et al., 1997/. Fertilization should take into account agrochemical analyses of the soil, purpose of growing, varietal characteristics and expected yield. Based on the reserves of nutrients available in the soil, one may predict the yield and programme fertilization aimed at achieving the expected yield /Krištaponytė, 2002/. Numerous software programmes of fertilizer rates are developed. They are relied on in selecting even more efficient fertilization rates /Švedas et al., 2000/.

Weather conditions are also important for grain yield and quality. The related reference material presents the data on the relationship between the spring barley yield and the rainfall in June and August /Dmitrenkova, 2004/. Protein content in grain is dependent on the varietal characteristics, cultivation technology and the weather conditions /Gluchovcev, 1996; Tamm, Tamm, 2002/. Analyses of the malting variety 'Trumpf' revealed finer and more protein-containing barley grain during sunny summers if compared with wet and moderately sunny summers /Gluchovcev, 1996/. It has been found that protein content in barley grain is mostly influenced by nitrogen fertilizers rather than other factors, while fractional composition of grain is more dependent on the environmental conditions /Tamm, Tamm, 2002/. Volume weight of grain and 1000 grain weight are primarily the indicators of a variety; however, they are also influenced by hydro-thermal coefficient of the growing season, sowing time, fertilization and plant protection measures /Pasynkov, 2002; Ivoilov et al., 2003/.

The tests were designed to determine the effect of the weather conditions and nitrogen fertilizers on the yield of spring barley grain and productivity components parameters and quality indices.

Material and Methods

Research was done at the Rumokai Experimental Station of the Lithuanian Institute of Agriculture during the period 1998-2000 and 2003-2004. The soil of the experimental site is *Hapli-Epihypogleyic Luvisol*. Precrop – sugar beet. Background of the experiments was fertilized with phosphorus and potassium fertilizers at a rate of 60 kg of active ingredient per hectare. Nitrogen fertilizer was applied at 0 kg ha^{-1} and 90 kg ha^{-1} of active ingredient. The tests involved the spring barley variety 'Alsa' developed at the Lithuanian Institute of Agriculture.

Barley was sown during the first ten-day period of May (and in the third ten-day period of April in 2000) at a seed rate of 4.5 million viable seed per hectare. At the start of stem development (30-31 BBCH) herbicide Dialen was sprayed at 1.5-2.0 l ha^{-1} and at the end of booting – beginning of heading stage (43-51 DK) fungicide Tango (0.8 l ha^{-1}) was applied. The crop was harvested during the second ten-day period of August.

Plant samples for biometrical analysis were taken before harvesting from four sites (0.25 m^2) of each experimental plot. At harvesting grain samples were taken for chemical analyses and for 1000 grain weight determination.

Package for statistical data processing ANOVA was used for statistical analysis /Tarakanovas, 2002/.

Weather conditions. It was dry and warm during the second half of April and at the beginning of May 1996 (Tables 2 and 3). Poor germination of barley resulted from the shortage of moisture in the soil. Heavy rains started in the second half of May, and germination of the remaining non-germinated grain took place. Delayed development plants emerged in the field. The weather in June was cool and dry. Cool weather was also typical of July and rainfall increased: the rate of rainfall in July was close to the level of several years' average. Warm and dry weather occurred in August – it was favourable for grain ripening and harvesting.

Table 1. The mean daily air temperature during the growing period of spring barley in Rumokai

1 lentelė. *Vidutinė paros oro temperatūra °C vasarinių miežių vegetacijos laikotarpiu*

Rumokai, 1996-2000, 2003-2004

Year *Metai*	Month *Mėnuo*				
	April *Balandis*	May *Gegužė*	June *Birželis*	July *Liepa*	August *Rugpjūtis*
Average of 1924-2003 *1924-2003 m. vidurkis*	6.1	12.2	15.5	17.6	16.4
1996	7.9	13.6	14.9	16.1	18.3
1997	4.9	11.7	16.7	18.6	19.2
1998	9.0	13.7	17.5	16.6	15.3
1999	9.5	9.6	18.9	22.1	16.6
2000	11.8	13.1	16.3	16.7	16.8
2003	5.4	13.1	16.2	20.0	17.8
2004	7.4	8.7	13.2	16.1	17.6

The spring of 1997 was cool and with a sufficient level of precipitation. Cool and rainy weather continued in May leading to tillering of crops. The summer of that year was warm and dry, thus the weather was unfavourable for diseases. The amount of rainfall never reached 50 % of the long-term average.

The spring of 1998 was warm with a sufficient amount of precipitation. The third ten-day period of April was without precipitation, and warm and sunny weather prevailed. It was warm, though rainy in May and June. The amount of rainfall was 1.8 times higher than the long-term average. The weather in August was cool and rainy, and unfavourable for harvesting.

The year 1999 was characterised by an early spring. An average monthly temperature in April was by 3.4 °C higher than the average temperature of many years. Cooler weather occurred at the beginning of May. The third ten-day period of May was characterised by dry, warm with even hot days extending during the whole period of barley growing. Unfavourable weather conditions were created for the development of barley deceases, which required moisture. As a result, foliar diseases were not abundant in 1999. In July the weather was warm and sufficiently dry and the crops ripened rapidly, which in turn resulted in an early harvesting.

Table 2. Rainfall during the growing period of spring barley in Rumokai
2 lentelė. *Kritulių kiekis mm vasarinių miežių vegetacijos laikotarpiu*
Rumokai, 1996-2000, 2003-2004

Year *Metai*	Month Mėnuo				
	April *Balandis*	May *Gegužė*	June *Birželis*	July *Liepa*	August *Rugpjūtis*
Average of 1924-2003 *1924-2003 m. vidurkis*	40.0	53.0	71.0	90.0	96.0
1996	29.0	61.3	39.9	104.4	12.2
1997	39.2	80.2	21.6	39.4	23.0
1998	65.1	30.0	126.5	159.5	111.9
1999	26.8	18.8	178.0	44.4	69.5
2000	8.9	38.3	143.0	395.6	91.5
2003	37.6	43.8	55.9	86.8	66.3
2004	44.4	62.0	94.2	86.8	74.2

The spring of 2000 was exceptionally early. The average air temperature in April was by 5.7 °C higher than the long-term average, and only one rainy day was reported during the whole month. Problematic and uneven germination of early-sown barley was reported due to the dry weather conditions. July was exceptionally rainy, when the amount of rainfall was by 4.4 times higher than the long-term average.

April of 2003 was cooler than the long-term average. The amount of precipitation was close to the long-term average. May, June and July were warm with sufficient amount of precipitation.

April of 2004 was quite early and with sufficient amount of precipitation. Average air temperature in May, June and July was lower than the long-term average. The amount of precipitation in April, May and July was close to the long-term average, while June was rainy.

Results and Discussion

Crop density and productive tillering. Although the seed rate was uniform during all experimental years, different crop density was observed (Table 3).

The highest crop density was reported in 1999, when the spring was early. The average temperature in April was by 3.4 °C higher than the long-term average, with 10 rainy days per month. These parameters resulted in the soil ready for spring sowing in the second half of April.

The sown crops germinated immediately and evenly. The spring of 2000 was exceptionally early. The average air temperature in April was by 5.7 °C higher than the long-term average, and only one rainy day was reported during the whole month. Problematic and uneven germination of early-sown barley was recorded due to the dry weather conditions.

Table 3. The effect of nitrogen fertilizers on spring barley crop density and number of productive stems

3 lentelė. *Azoto trąšų sąlygų įtaka vasarinių miežių tankumui ir produktyvių stiebų skaičiui*

Rumokai, 1996-2000, 2003-2004

Year *Metai*	Not-fertilized *Azotu netręšta*	N_{90} kg ha^{-1}	LSD_{05} R_{05}
	Crop density plants m^{-2} *Augalų tankumas vnt. m^{-2}*		
1996	200	188	37.8
1997	215	202	47.7
1998	266	251	32.0
1999	299	348	56.2
2000	105	108	27.2
2003	186	194	30.2
2004	193	197	31.7
	Number of productive stems m^{-2} *Produktyvių stiebų skaičius vnt. m^{-2}*		
1996	492	689	180.2
1997	532	682	111.6
1998	617	688	93.1
1999	531	714	183.2
2000	502	539	66.8
2003	553	670	88.7
2004	511	629	98.1

The crop density was very low, only 105-108 plant m^{-2}. A considerable influence on density was exerted by precipitation in April (correlation coefficient – 0.46**) (Table 4). The more precipitation is available before drilling, the more moisture content of soil and more favourable conditions for barley germination are ensured. No effect of nitrogen fertilizers on the crop density was established during this trial.

The statistical analysis revealed that the crop density had no direct impact on the grain yield but it exerted some effect on the number of productive stems and the number of grain per ear (correlation coefficients – 0.30** and – 0.64**) (Table 5).

An important component of the yield structure, the number of productive stems in the trial fields non-fertilized with nitrogen fertilizers, was the largest in 1998 when moisture content was sufficient for barley at tillering stage (Table 3). Optimal weather conditions were recorded during the barley germination in 1999, but too little rainfall fell at a later stage, during barley tillering, when barley is especially vulnerable to the shortage of moisture. In May the amount of rainfall was only 35.5 % of the long-term average. For this reason the number of productive stems was smaller than in 1998. The lowest number of productive stems was found in 2000. Complex germination of barley in 2000 was due to an extremely dry and hot spring. Some precipitation occurred during tillering stage, but it had no major impact on productive tillering of barley as a result of high air temperature and very dry soil.

Table 4. The correlation coefficients between spring barley yield, its biological components, precipitation and nitrogen fertilizers
4 lentelė. *Koreliacijos koeficientai tarp vasarinių miežių grūdų derliaus, jo biologinių parametrų ir aplinkos veiksnių*

Rumokai, 1996-2000, 2003-2004

Characteristic *Požymis*	Precipitation in April mm *Krituliai mm per balandį*	Precipitation in May mm *Krituliai mm per gegužę*	Precipitation in June mm *Krituliai mm per birželį*	Precipitation in July mm *Krituliai mm per liepą*
Grain yield t ha^{-1} *Grūdų derlius t ha^{-1}*	0.26	0.81**	-0.93**	-0.41*
Crop density plants m^{-2} *Augalų tankumas vnt. m^{-2}*	0.46**	-0.27	-	-
Productive stems number m^{-2} *Produktyvūs stiebai vnt. m^{-2}*	0.32*	0.06	-0.15	-0.24
Number of grains per ear *Grūdų skaičius varpoje*	0.23	0.46**	-0.45**	0.41*
1000 grain weight g *1000-čio grūdų masė g*	-0.92**	0.35*	-0.16	0.38*
Protein content in grain % B*altymų kiekis grūduose %*	0.06	-0.75**	0.74**	-0.14
Protein yield t ha^{-1} B*altymų derlius t ha^{-1}*	0.47**	0.46**	-0.59**	-0.32*

Table 5. The correlation coefficients between spring barley yield and its biological components
5 lentelė. *Koreliacijos koeficientai tarp vasarinių miežių grūdų derliaus ir jo biologinių parametrų*

Rumokai, 1996-2000, 2003-2004

Characteristic / *Požymis*	Coefficients of correlation / *Koreliacijos koeficientai*					
	2	3	4	5	6	7
Grain yield t ha^{-1} *Grūdų derlius t ha^{-1}*	-0.13	0.31*	0.59**	-0.18	-0.47**	0.93**
Crop density plants m^{-2} *Augalų tankumas vnt. m^{-2}*		0.30*	-0.64**	-0.60**	0.58**	0.07
Productive stems number m^{-2} *Produktyvūs stiebai vnt. m^{-2}*			0.04	-0.36*	0.31*	0.48**
Number of grains per ear *Grūdų skaičius varpoje*				0.03	-0.61**	0.47**
1000 grains weight g *1000-čio grūdų masė g*					-0.30*	-0.35*
Protein content in grain % *Baltymų kiekis grūduose %*						-0.14
Protein yield t ha^{-1} *Baltymų derlius t ha^{-1}*						1.0

Formation of the number of productive stems was influenced by nitrogen fertilization rather than by the weather conditions. It was the most evident in 1998, when comparison was made between nitrogen non-fertilized trial fields and those fertilized with 90 kg ha^{-1} nitrogen fertilizers. The number of productive stems increased by 40.0 %.

The number of grain per ear was not uniform in different experimental years (Table 6). The smallest number was observed in 1999. In nitrogen non-fertilized fields the number of grain was by 37.2 % smaller than in 2000. The reduction in the number of grain was due to the unfavourable weather conditions. Compared with the long-term average, rainfall in May and July was only 34.2 % and 44.4 % respectively, and June was rainy. Besides, the crop of 1999 was very much damaged by thrips. Nitrogen fertilizers had no major influence on the number of grain per ear.

1000 grain weight was the highest in 2000 (Table 6). It was due to sparse crop of that year. Statistical calculations between the barley density and weight of 1000 grain revealed a medium negative correlation (correlation coefficient – -0.60**) (Table 4). 1000 grain weight had strong correlation with precipitation in April – correlation coefficient was -0.92**. A sufficient amount of moisture during sowing stimulated both, germination of grain and the density of crop, so the weight of grain reduced. Also, 1000 grain weight was influenced by the rainfall in July (correlation coefficient 0.38*) – larger amount of rainfall during grain filling stimulated an increase in the grain weight.

Table 6. The effect of nitrogen fertilizers on the number of grain per ear and 1000 grain weight

6 lentelė. *Azoto trąšų įtaka vasarinių miežių grūdų skaičiui varpoje ir 1000-čio grūdų masei*

Rumokai, 1996-2000, 2003-2004

Year *Metai*	Not-fertilized *Azotu netręšta*	N_{90} kg ha^{-1}	LSD_{05} R_{05}
	Number of grain per ear *Grūdų skaičius varpoje*		
1996	21	22	0.45
1997	21	22	0.98
1998	21	22	0.82
1999	14	15	0.98
2000	22	22	0.86
2003	21	22	0.89
2004	21	21	0.96
	1000 grains weight g *1000-čio grūdų masė g*		
1996	50.6	49.1	2.53
1997	48.6	47.8	2.12
1998	41.6	41.1	0.85
1999	46.7	47.5	1.69
2000	54.8	53.5	1.22
2003	49.8	49.2	1.65
2004	44.7	43.2	1.86

Nitrogen fertilizers increased the density of productive stems and stimulated foliar diseases but reduced 1000 grain weight. A marked reduction in the grain size was found in 2004. The decisive factor was intensive development of foliar diseases and barley lodging.

The highest grain yield was registered in the years 1996 and 1997 (Table 7). It was due to the favourable moisture content during germination and growing periods and dry weather conditions during flowering. The lowest grain number was reported in 1999 due to the thrips and rainy weather in June which reduced the number of grain per barley ear. The grain yield was largely influenced by the weather conditions. Statistical calculations revealed that the major impact on the grain yield was due to the rainfall in May and June (Table 4).

Table 7. The effect of nitrogen fertilizers on grain yield, protein content in grain and protein yield
7 ***lentelė.*** *Azoto trąšų įtaka vasarinių miežių grūdų derliui, baltymų kiekiui grūduose ir baltymų derliui*

Years *Metai*	Not-fertilized *Azotu netręšta*	N_{90} kg ha^{-1}	LSD_{05} R_{05}
	Grain yield t ha^{-1} / *Grūdų derlius t ha^{-1}*		
1996	5.30	5.86	0.555
1997	5.01	6.76	1.045
1998	4.56	4.92	0.411
1999	2.14	3.27	0.241
2000	2.96	3.93	0.480
2003	4.57	5.47	0.456
2004	3.75	4.64	0.502
	Protein content in grain % / *Baltymų kiekis %*		
1996	11.8	12.1	0.07
1997	10.7	12.2	0.70
1998	12.7	13.8	0.58
1999	14.9	15.8	0.88
2000	11.8	13.2	1.51
2003	11.9	13.1	0.98
2004	12.3	13.5	0.77
	Protein yield t ha^{-1} / *Baltymų derlius t ha^{-1}*		
1996	0.51	0.60	0.065
1997	0.46	0.70	0.077
1998	0.49	0.58	0.059
1999	0.27	0.43	0.029
2000	0.30	0.43	0.069
2003	0.46	0.61	0.055
2004	0.39	0.53	0.048

The rainfall in May directly correlated with the grain yield (correlation coefficient 0.81**). The rainfall in June stimulated the development of diseases and reduced the productivity of barley (correlation coefficient – -0.93**). Besides, precipitation of this month had a negative influence on the number of grain per ear and direct positive correlation was established between the number of grain and the yield (correlation coefficient – 0.59**). During all experimental years the application of nitrogen fertilizers increased the grain yield.

The data in the reference material inform about the decisive factors on the *protein content* in spring barley to be meteorological conditions and the soil micro-variety rather than the genetic potential of a crop /Mašauskienė et al., 2001/. Our tests also revealed that protein content in the grain was very much affected by the weather conditions (Table 7). It was dry and hot in 1999 at the grain formation stage. Besides, the soil was high in mineral nitrogen before sowing that year (50.30 kg ha^{-1}) and for this reason the grain of spring barley had high protein content (14.87-15.75 %).

Statistical analyses pointed at a medium inverse correlation between the rainfall in May and protein content in grain, and direct correlation between the rainfall in June and protein content in grain. Medium negative correlation was determined between the grain yield and protein content in the grain – the larger yield, the less protein content in the grain. All experimental years revealed that nitrogen fertilizers increased protein content in grain by 2.8-13.8 %.

The protein yield (the content of protein derived from one hectare) differed between the experimental years and was the most dependent on the grain yield (correlation coefficient – 0.93**) (Table 7.). No correlation was determined between the protein content in grain and the protein yield. As for environmental factors, positive influence on the protein yield was exerted by precipitation in April and May. The rainfall in June reduced the protein yield (correlation coefficient -0.59**).

Conclusions

1. The lowest spring barely population density was identified in 2000, as a result of 22 % of the precipitation in April compared with the long-term average. The crop density had no direct effect on the grain yield, though it correlated with the number of productive stems and the number of grain per ear.

2. The lowest number of productive stems was recorded in 2000. Nitrogen fertilization increased the number of productive stems. The positive effect on the number of productive stems was due to the precipitation in April.

3. Medium strong correlation was found between the number of grain per ear and the grain yield. Rainfall in May and July increased the number of grain (correlation coefficients 0.46** and 0.41**); the negative impact on the said parameter was exerted due to the rainfall in June.

4. The lowest number of grain was reported in 1999, thrips and rainy weather in June reduced the number of grain per ear. A significant influence on the grain yield was exerted by the rainfall in May and June. Application of nitrogen fertilizer at 90 kg ha^{-1} rate resulted in a higher grain yield during all experimental years.

5. High protein content in grain was recorded in 1999, when the lowest grain yield was produced. Medium strong negative correlation was identified between the grain yield and protein content in grain – the better yield, the lower protein content in grain. Medium strong inverse correlation was determined between rainfall in May and protein content in grain, and direct correlation was found between rainfall in June and protein content in grain.

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AZOTO TRĄŠŲ IR METEOROLOGINIŲ SĄLYGŲ ĮTAKA VASARINIŲ MIEŽIŲ GRŪDŲ DERLIUI IR PRODUKTYVUMO KOMPONENTAMS

Z. Brazienė

Santrauka

LŽI Rumokų bandymų stotyje 1998-2000 m. ir 2003-2004 m. tirtas vasarinių miežių veislės 'Alsa' grūdų derliaus ir jo biologinių parametrų bei baltymų kiekio priklausomumas nuo azoto trąšų ir meteorologinių sąlygų. Bandymai daryti paprastajame sekliai glėjiškame išplautžemyje. Azoto trąšų 90 kg ha^{-1} norma lyginta su netręšto varianto miežių 'Alsa' grūdų derliumi.

Tyrimų duomenimis, vasarinių miežių grūdų derlius teigiamai ir patikimai koreliavo su gegužės mėnesio kritulių kiekiu (koreliacijos koeficientas 0,81**) ir neigiamai patikimai su birželio ir liepos mėnesių kritulių kiekiu (koreliacijos koeficientai -0,93** ir -0,41*). Tarp azoto trąšų kiekio ir grūdų derliaus buvo esminė, tačiau silpna koreliacija. Atlikus statistinius skaičiavimus tarp grūdų derliaus ir jo biologinių parametrų, paaiškėjo, kad derliaus dydis labiausiai priklausė nuo produktyvių stiebų skaičiaus ir grūdų kiekio varpose. Produktyvių stiebų skaičiui azoto trąšos turėjo didesnę įtaką negu meteorologinės sąlygos, o grūdų kiekis varpose labiau priklausė nuo gegužės ir birželio mėnesių kritulių kiekio. Miežių tankumas grūdų derliui tiesioginės įtakos neturėjo, tačiau jis veikė produktyvių stiebų skaičių ir grūdų kiekį varpose. Baltymų derlius stipriai koreliavo su grūdų derliumi ir mažai priklausė nuo baltymų koncentracijos grūduose. Tarp azoto trąšų ir baltymų derliaus nustatyta vidutinė teigiama koreliacija.

Reikšminiai žodžiai: vasariniai miežiai, derlius, baltymų kiekis grūduose, azoto trąšos, kritulių kiekis.